






BMJ Open Identifying characteristics that enable resilient immunisation programmes: a scoping review

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ABSTRACT

Objectives The COVID-19 pandemic highlighted the fragility of immunisation programmes and resulted in a significant reduction in vaccination rates, with increasing vaccine-preventable disease outbreaks consequently reported. These vulnerabilities underscore the importance of resilient immunisation programmes to ensure optimal performance during crises. To date, a framework for assessing immunisation programme resilience does not exist. We conducted a scoping review of immunisation programmes during times of crisis to identify factors that characterise resilient immunisation programmes, which may inform an Immunisation Programme Resilience Tool.

Design Scoping review design followed the Arksey and O'Malley framework, and manuscript reporting followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews guidelines.

Data sources CINAHL, CENTRAL, Embase, Google Scholar, MEDLINE, PsycINFO and Web of Science and databases were searched between 1 January 2011 and 2 September 2023. Citation searching of identified studies was also performed.

Eligibility criteria We included primary empirical peer-reviewed studies that discussed the resilience of immunisation programme to crises, shocks or disruptions.

Data extraction and synthesis Two independent reviewers screened records and performed data extraction. We extracted data on study location and design, crisis description, and resilience characteristics discussed, and identified evidence gaps in the literature. Findings were synthesised using tabulation and an evidence gap map.

Results Thirty-seven studies met the eligibility criteria. These studies captured research conducted across six continents, with most concentrated in Africa, Asia and Europe. One study had a randomised controlled trial design, while 36 studies had observational designs (15 analytical and 21 descriptive). We identified five characteristics of resilient immunisation programmes drawing on the Health System Resilience Index (Integration, Awareness, Resource Availability and Access, Adaptiveness and Self-regulation) and several evidence gaps in the literature.

Conclusions To our knowledge, no immunisation programme resilience tool exists. We identified factors from the Health System Resilience Index coupled with factors identified through primary empirical evidence,

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This scoping review used a comprehensive search for articles in peer-reviewed journals, with all search strategies being independently peer-reviewed using the PRESS checklist.
- ⇒ All underlying data and code are provided without the need for a request to facilitate transparency and reproducibility.
- ⇒ Given the inherent challenges of studying immunisation programmes during times of crisis, most of the literature on this topic is observational, limiting the ability to make claims of causality.
- ⇒ For this review, searches were limited to peer-reviewed journals, thus further insights may be gained in the future by extending the search to grey literature.

which may inform development of an immunisation programme resilience tool.

INTRODUCTION

Global immunisation is one of public health's major success stories.¹ In addition to reducing morbidity and mortality in vaccinated individuals, immunisation programmes have broad socioeconomic and societal value, including indirect benefits to unvaccinated individuals through community protection and alterations to pathogen epidemiology that limit epidemic cycles.²⁻⁴ The global crisis caused by the COVID-19 pandemic highlighted the fragility of immunisation programmes, as national pandemic preparedness plans were tested and weaknesses exposed in both COVID-19 and routine immunisation delivery.⁵⁻⁸ This has resulted in significant reductions in vaccination coverage rates,^{7 9 10} with increasing vaccine-preventable disease outbreaks as a consequence.⁸ These vulnerabilities emphasise the urgent need to make immunisation programmes more resilient, to ensure they can maintain optimal performance during times of crisis.

The concept of resilience is conceptualised around ‘disaster readiness’ and is often applied to individuals, communities and cities, as well as physical, ecological and social systems.¹¹ More recently, the concept has been adapted to healthcare systems, defined as ‘the capacity of health actors, institutions and populations to prepare for and effectively respond to crises; maintain core functions when a crisis hits; and, informed by lessons learnt during the crisis, reorganise if conditions require it’,¹² and the ability to ‘withstand major shocks and disruptions, to quickly adapt to changing circumstances, and to maintain high utilisation and demand over time’.¹³

In response to the 2013–2016 Ebola epidemic in West Africa, Kruk *et al* formulated a Health System Resilience Index.¹⁴ In three case studies (influx of refugees in Lebanon, Ebola epidemic in Liberia and natural disasters in Indonesia), applying concepts in this health system resilience framework enabled these countries to recover from shocks that stressed their health systems.¹⁴ To date, there does not appear to be an equivalent resilience framework that is specific to immunisation programmes, and the appropriateness of applying a health system index to immunisation programmes has not been assessed, which would be of great value.

In this scoping review, we explored key characteristics that would inform the development of a resilience framework specific for immunisation programmes. Due to the challenges of conducting research during times of crisis, primary empirical research is scarce. We, therefore, used the Health System Resilience Index developed by Kruk *et al*^{12,14} as an initial framework that could be adapted for use with immunisation programmes based on research identified in our review. We selected this index due to its broad conceptual framework and applicability across three case studies. We assessed the appropriateness of adapting the index for assessing immunisation programme resilience and assessed evidence gaps in the literature to draw attention to potential blind spots.

METHODS

Search strategy and selection criteria

Our review protocol was written according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA) guidelines^{15,16} and was originally registered on the Open Science Framework (OSF)¹⁷ on 11 January 2022 (<https://doi.org/10.17605/OSF.IO/TRXX2>). Following peer review, changes to the protocol were made to clarify the review aims and broaden the literature search. An updated protocol indicating all updates from the original version as tracked changes is available on OSF (<https://doi.org/10.17605/OSF.IO/6N2G3>).

We conducted the review using the Arksey and O’Malley framework¹⁸ and reported information in line with PRISMA for Scoping Reviews guidelines.¹⁹ The research questions that we addressed were as follows: (1) is the Health System Resilience Index¹⁴ suitable for assessing immunisation programme resilience? and (2) what are

the major gaps in primary empirical research in assessing immunisation programme resilience? Our review questions are presented in PICO (Population, Intervention, Comparison and Outcome) format in online supplemental information S1.1, table S1.

Our eligibility criteria are tabulated in online supplemental information S1.2 (table S2 inclusion criteria and table S3 exclusion criteria). We included primary empirical research studies with any study design²⁰ that were published in peer-reviewed journals. We did not review grey literature. We assume that the immunisation programme resilience characteristics discussed in primary empirical research papers are representative of characteristics published in the grey literature. As the qualitative descriptive outcomes considered in this review are likely less subject to selective reporting and publication bias than quantitative and hypothesis-based outcomes, the impact of this approach is lessened. We also restrict our search to the decade preceding the commencement of this review (from 1 January 2011 onwards). The concept of resilient health systems is relatively new, as recently outlined,^{12,14} and discussion of its application to immunisation programmes is as recent as the development of the 2017 Health System Resilience Index.¹⁴ No further limits were applied.

We searched MEDLINE (Ovid), Embase (Ovid), PsycINFO (Ovid), CINAHL (EBSCO), CENTRAL (Wiley), Web of Science (SCI-EXPANDED and SSCI; Clarivate Analytics), and the top 200 hits from Google Scholar.²¹ The search was run on 2 September 2023, thus including publications from 1 January 2011 to 2 September 2023. The search strategies were developed to identify publications that mention both the keywords ‘immunisation programme’ and ‘resilience’ (as well as several variations on these keywords), filtered out ineligible publication types (eg, reviews, editorials), and applied a publication date limit from 1 January until the date the search was run. No other limits or filters were applied, and the review was not limited to non-English language publications. Our search strategies were independently peer-reviewed using the Peer Review of Electronic Search Strategies (PRESS) checklist²² by Kat Steiner, an Outreach Librarian at the Bodleian Health Care Libraries, University of Oxford. All search strategies are presented in full in online supplemental information S1.3.

The search results were deduplicated and screened using EPPI-Reviewer Web (ER-Web).²³ Study selection was a two-stage process: screening on title and abstract followed by screening on full text. The screening was carried out in duplicate by two independent reviewers and disagreements were settled by discussion between both reviewers. Finally, we performed citation searching on the reference lists of all studies included in the review after screening.²⁴

Data extraction

From each study, we extracted basic publication information data (eg, publication year), study design, crisis

type, geographical location, disease targeted by immunisation programme and resilience characteristic discussed based on the 2017 Health System Resilience Index.¹⁴ The data extraction form was developed in an iterative process and involved an initial piloting stage where five studies were independently data extracted by two reviewers, with disagreements and refinements to the data extraction form agreed through discussion. Data extraction on the remaining studies was first performed by a single reviewer and then validated by a second reviewer, with disagreements settled by discussion between both reviewers. Data extraction was performed using ER-Web.

The study design was assessed at two levels.²⁰ The first level depended on whether the study investigators assigned the exposures: affirmative for experimental studies; negative for observational studies. The second level specified the experimental and observational studies further. For experimental studies, this was determined by whether the exposure allocations were random: affirmative for randomised controlled trials (RCTs); negative for non-RCTs. For observational studies, this was determined by whether a comparison group was included: affirmative for analytical studies; negative for descriptive studies.

We classified the crisis type in each study using the PESTLE (Political, Economic, Social, Technological, Legal, Environmental) taxonomy²⁵ and by specific crisis described. PESTLE crises were categorised as political if related to government interventions and actions; economic if related to, for example, inflation, exchange rates or economic growth; social if related to public demand, traditional or social media coverage, or armed conflict; technological if related to Research and Development (R&D) activity, automation, or IT; legal if related to the law or changes in the law; and environmental if related to disease outbreak, natural disasters or other ecological or environmental events. PESTLE categories were treated as non-exclusive.

Geographical location was extracted by continent (Africa, Asia, Australia, Europe, North America or South America; defined geographically) and country. The disease type targeted by the immunisation programme was extracted as reported in the publication. Lastly, the resilience index being considered was listed as described by the original investigators.

Data analysis

We charted the primary outcome variables using the Health System Resilience Index outlined by Kruk *et al.*,¹⁴ which contains five resilience characteristics:

- ▶ **Aware:** Tracks population health threats; maps systems strengths and weaknesses; knows available resources.
- ▶ **Integrated:** Coordinates between government, global and private actors; works across sectors; involves communities.
- ▶ **Diverse:** Addresses range of health problems; provides quality services that meet population needs.

- ▶ **Self-regulating:** Isolates health threats; minimises disruption to essential services; can access reserve capacity.
- ▶ **Adaptive:** Transforms operations to improve function; acts on evidence and feedback; encourages flexible response to fit situation.

We used an adaptive approach to charting this outcome variable based on the studies reviewed. Adaptations were discussed by authors and the data charting form was updated using an iterative process.

The primary results were tabulated in detail, displayed in summary using bar charts and synthesised narratively. An evidence gap map was generated (using EPPI-Mapper V.2.2.4) to highlight evidence gaps in the literature to draw attention to potential blind spots.

Role of funding source

Employees of the funder were involved in the design and conduct of the study; collection, management, analysis and interpretation of the data; preparation, review or approval of the manuscript and decision to submit the manuscript for publication.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

RESULTS

Study selection and study characteristics

We identified 37 studies^{26–62} that were eligible for this review: 29 from databases and 8 from citation searching. The study selection process is displayed in [figure 1](#). Specific characteristics for each included study are presented in online supplemental table S4, with summaries of the study characteristics presented in [figure 2](#).

Over 97% (36/37) of identified studies were published from 2016 onwards ([figure 2A](#)). The majority of these adopted either a descriptive (21/37) or analytical (15/37) study design, with only a single RCT³⁰ design identified ([figure 2B](#)).

Crises that occurred were predominantly environmental (26/37): 18 were due to the COVID-19 pandemic, 5 were due to the 2013–2016 Ebola epidemic, 2 were due to hurricanes and 1 was due to an earthquake. There were nine studies on social crises, two were on legal and one was on political crises. We did not identify any publications on either economic or technological crises impacting immunisation programmes ([figure 2C](#)).

Most studies reported on crises in Africa, Asia or Europe (12 studies in each continent). Six studies reported on crises in North America, and only three studies originated from both South America and Australia ([figure 2D](#)).

While some studies considered the resilience of a specific immunisation programme, several studies considered the resilience of a national immunisation

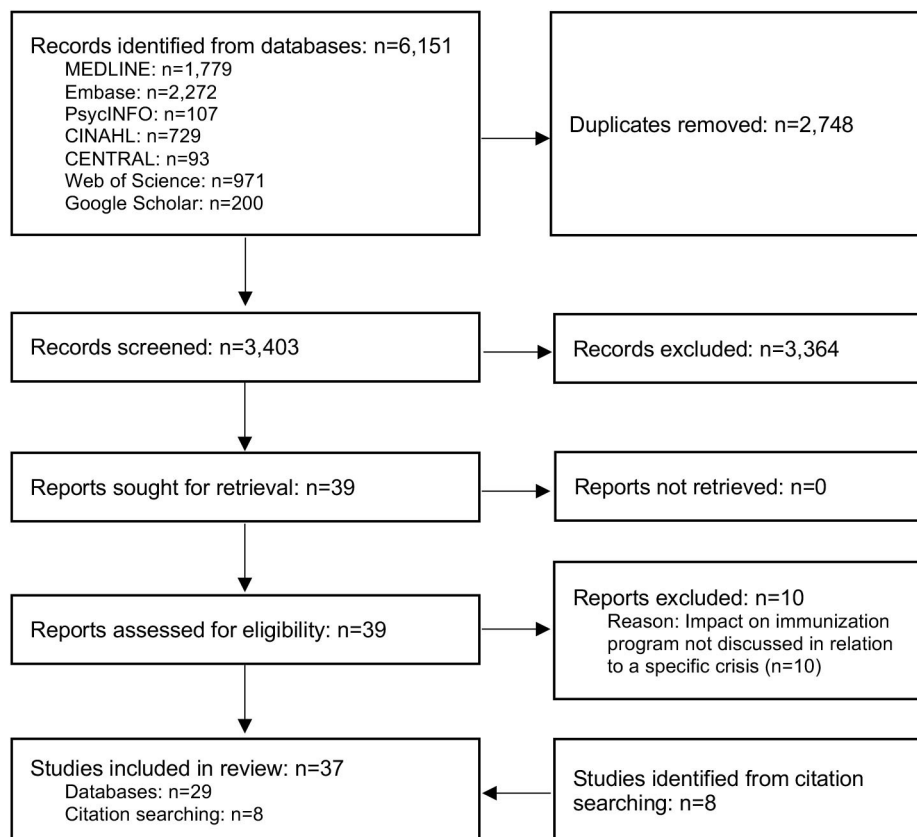


Figure 1 PRISMA flow diagram of study selection process. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

programme. As a result, charting studies by specific diseases were not possible.

Immunisation programme resilience characteristics

Based on our research, we identified five resilience characteristics that may form the basis of an Immunisation Programme Resilience Framework: (1) Integration, (2) Adaptiveness, (3) Resource Availability and Access, (4) Self-regulation and (5) Awareness (figure 3 and table 1). Four characteristics (Integration, Adaptiveness, Self-regulation, Awareness) are consistent with the Health System Resilience Index characteristics; one was identified based on the literature search as a key characteristic that should be taken into account. To clarify the scope and distinction between each of these characteristics, we put forward a one-sentence description outlining their scope when applied to immunisation programmes, which we used for this review (figure 3 and table 1).

Factors identified within the Integration category primarily focused on the need for cohesion within and between immunisation programmes and stakeholders. This included integration of community-based health-care programmes, interdepartmental and interagency integration, and the importance of education, transparency, and trust between stakeholders. For Awareness, having well-developed data collection systems was considered core to successful monitoring of immunisation programmes, which included careful monitoring

of media reporting, vaccine uptake, and response and recovery activities. Resource Availability and Access was also critical to ensure that the required capacity for maintaining stable performance can be met, as well as the ability to access these resources during times of crisis. Examples of critical resources included financing (eg, performance-based financing), having appropriate supply chain infrastructure, staffing, personal protective equipment and standard operating procedures and guidelines in place to deal with unexpected scenarios. The importance of having an adaptive system was also highlighted, such that programmes are updated based on new circumstances and lessons learnt. Primarily this was achieved through rapid local decision-making and accountability for misconduct. Finally, Self-regulation was considered important to immunisation programmes by ensuring a continuous approach to monitoring, evaluating, reviewing, investigating and resolving new issues as they arise.

The five resilience characteristics were specifically refined in the context of immunisation programmes. For example, communication is repeatedly identified as a crucial element in a resilient programme. The reviewed literature frequently highlighted that communication plays a fundamental role in education and outreach efforts in integrating immunisation programmes, with a particular focus on public communication strategies to

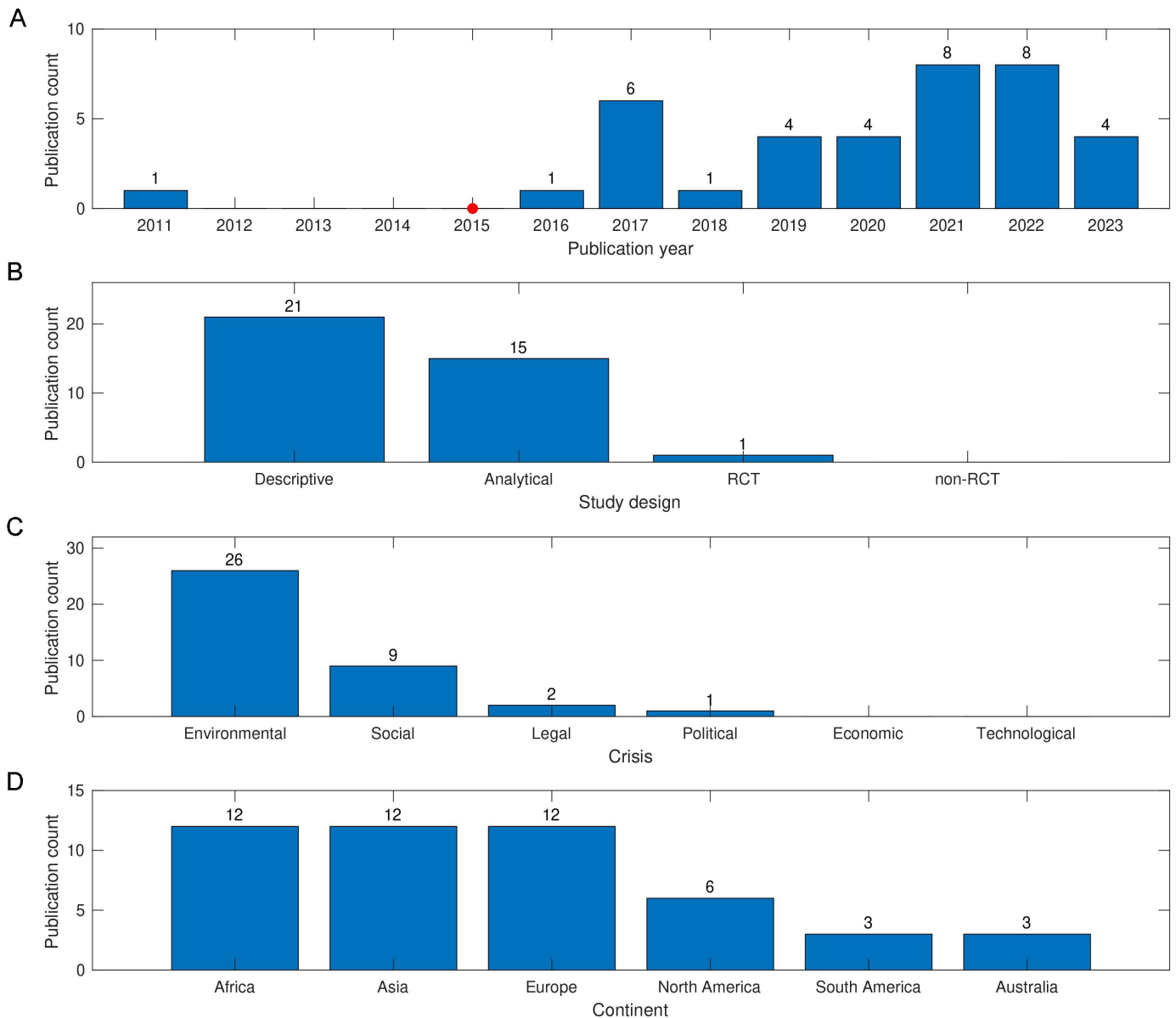


Figure 2 Summary of study characteristics. The details for each individual study are provided in online supplemental table S4. (A) Number of studies published per year. Our literature search spanned from 2011 to 2023. The red dot on 2015 indicates the year ‘What is a resilient health system? Lessons from Ebola’¹² was published. This paper is the precursor to the *Health System Resilience Index* published in 2017.¹⁴ The novelty of the concept of resilient health systems is outlined in these publications. Applying the concept of resilience to immunisation programmes appears to reflect the novelty of applying the concept to health systems, with only a single relevant publication being identified pre-2016. (B) Number of studies adopting observational (descriptive or analytical) or experimental (RCT or non-RCT) study designs. (C) Number of studies reporting on crisis type, categorised according to the PESTLE taxonomy. (D) Number of studies per continent. RCT, randomised controlled trial.

address vaccine fears, hesitancy and mistrust. Based on these observations, we classified communication under the Integration characteristic. We limited the Awareness characteristic to information collection, which can be viewed as encompassing monitoring, surveillance, tracking, etc. Thus, the Awareness characteristic encompasses monitoring systems such as immunisation information systems (confidential, population-based, computerised databases that record all immunisation doses administered by participating providers to persons residing within a given geopolitical area)⁶³ and adverse events following immunisation systems (any untoward

medical occurrence which follows immunisation and which does not necessarily have a causal relationship with the usage of the vaccine).⁶⁴

We distributed the aims of the Diverse characteristic of the Health System Resilience Index among (1) the Integration and (2) the Resource availability and Access characteristics. The Health System Resilience Index outlines two aims for the Diverse characteristic: (1) to effectively respond to a range of health needs and (2) to adequately finance health systems; prevent financial harm.¹⁴ The first aim was incorporated into the Integration characteristic of the Immunisation Programme Resilience Framework,

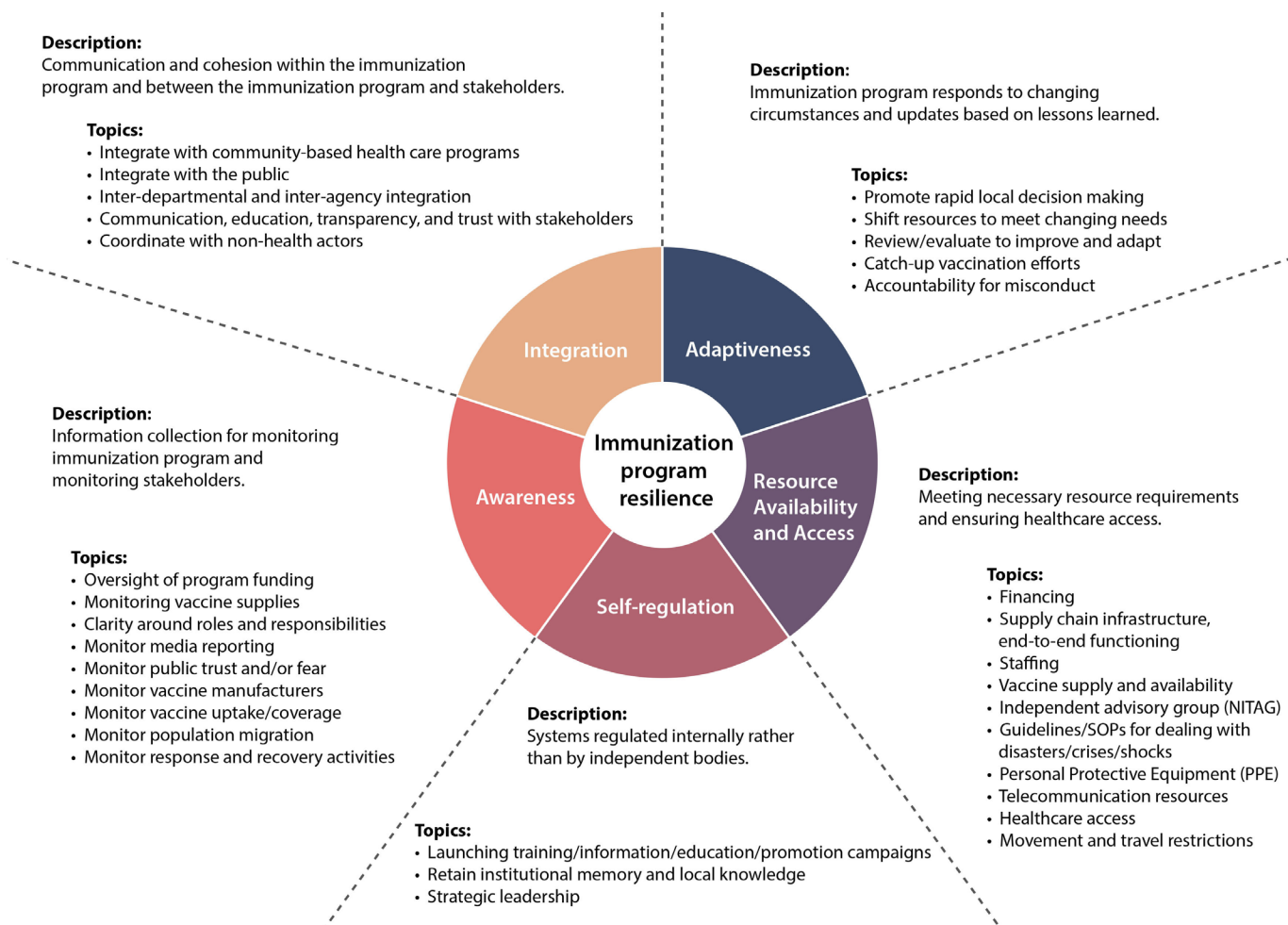


Figure 3 Immunisation programme resilience framework. NITAG, National Immunisation Technical Advisory Group; SOPs, standard operating procedures.

while the second aim was incorporated into the novel Resource Availability and Access characteristic.

A frequently identified and discussed characteristic in the reviewed studies, which was not present in the Health System Resilience Index, was Resource Availability and Access (26/37 studies). Examples of topics included in the Resource Availability and Access characteristic are outlined in table 1 and figure 3, and include healthcare workers' access to adequate supplies of PPE⁴⁸ or the public's access to medical facilities, which can be hindered due to movement or travel restrictions.^{46 48}

The overall characteristics, proposed in figure 3 and table 1, comprehensively incorporate all factors identified in this scoping review as being essential features of a resilient immunisation programme. Of the five Immunisation Programme Resilience Framework characteristics, Integration (26/37 studies) and Resource Availability and Access (26/37 studies) were most often discussed, followed by Awareness (24/37 studies), Adaptiveness (21/37 studies) and Self-regulation (11/37 studies) (table 1).

Gaps in primary empirical research into immunisation programme resilience

We displayed evidence gaps using an online interactive evidence gap map: <https://lukebax.github.io/resilience>.

This map displays studies by continent on the x-axis versus crisis on the y-axis, with experimental design indicated by colour coding. In each cell of the two-by-two grid, the size of each circle is proportional to the number of studies, and gaps in the research are visible as empty cells. Titles, abstracts and links to all publications are embedded in the map.

Evidence on environmental crises was identified across all continents. Social crises were identified in only Asia and Europe. Studies on legal crises originated from Europe only, and a study on political crises originated from Asia only. From this map, it is clear there are significant gaps in our evidence base for understanding the impact of crises on immunisation programmes across the globe.

DISCUSSION

We undertook a scoping review to identify factors that characterise resilient immunisation programmes and conducted a synthesis of the evidence to inform the development of an Immunisation Programme Resilience Framework. We identified 37 primary research studies that examined immunisation programmes during

Table 1 Immunisation programme resilience framework characteristics

Characteristic	Description	Topics	Hits
Integration	Communication and cohesion within the immunisation programme and between immunisation programme and stakeholders.	<ul style="list-style-type: none"> ▶ Integrate with community-based healthcare programmes ▶ Integrate with the public ▶ Interdepartmental and interagency integration ▶ Communication, education, transparency and trust with stakeholders ▶ Coordination with non-health actors 	70% (26/37)
Resource Availability and Access	Meeting necessary resource requirements and ensuring healthcare access.	<ul style="list-style-type: none"> ▶ Financing ▶ Supply chain infrastructure, end-to-end functioning ▶ Staffing ▶ Vaccine supply and availability ▶ Independent advisory group (NITAG) ▶ Guidelines/SOPs for dealing with disasters/crises/shocks ▶ Personal protective equipment ▶ Telecommunication resources ▶ Healthcare access ▶ Movement and travel restrictions 	70% (26/37)
Awareness	Information collection for monitoring immunisation programme and stakeholders.	<ul style="list-style-type: none"> ▶ Oversight of programme funding ▶ Monitoring vaccine supplies ▶ Clarity around roles and responsibilities ▶ Monitor media reporting ▶ Monitor public trust and/or fear ▶ Monitor vaccine manufacturers ▶ Monitor vaccine uptake/coverage ▶ Monitor population migration ▶ Monitor response and recovery activities 	65% (24/37)
Adaptiveness	Immunisation programme responds to changing circumstances and evolves based on lessons learnt.	<ul style="list-style-type: none"> ▶ Promote rapid local decision-making ▶ Shift resources to meet changing needs ▶ Review/evaluate to improve, adapt and evolve ▶ Catch-up vaccination efforts ▶ Accountability for misconduct 	57% (21/37)
Self-regulation	Systems regulated internally rather than by independent bodies.	<ul style="list-style-type: none"> ▶ Launching training/information/education/promotion campaigns ▶ Retain institutional memory and local knowledge ▶ Strategic leadership 	30% (11/37)

NITAG, National Immunisation Technical Advisory Groups; SOPs, standard operating procedures.

times of crisis that are relevant to the characterisation of programme resilience. We adapted the Health System Resilience Index, initially developed by Kruk *et al.*¹⁴ To our knowledge, this is the first attempt to synthesise evidence on immunisation programme resilience to be used to inform development of an Immunisation Programme Resilience Framework.

Our overarching aim was to identify characteristics that enable the development of resilient immunisation programmes, using the Health System Resilience Index as a useful foundational framework, rather than to develop or refine the Health System Resilience Index. It is important that immunisation programmes do not aim to function independently from other components of health system delivery, but strive to integrate within the larger health system. Our review aims to align with the Immunization Agenda 2030 (IA2030) to promote equitable immunisation coverage. Our review helps to provide data-guided evidence to support IA2030 strategic priorities to ensure equitable immunisation service delivery during emergencies, such as human conflicts, natural disasters and other humanitarian crises.

Overall, we found the Health System Resilience Index to be an appropriate foundation for creating an Immunisation Programme Resilience Framework. Of the five

Health System Resilience Index characteristics (Aware, Integrated, Diverse, Self-regulating, Adaptive), four (Awareness, Integration, Self-regulation, Adaptiveness) are featured in our framework. We identified Resource Availability and Access as a salient characteristic in 70% of studies meeting the eligibility criteria (eg, healthcare workers' access to adequate supplies of PPE⁴⁸ and the public's access to medical facilities, which can be hindered by movement or travel restrictions).^{46 48} Additionally, we distributed the aims of the Diverse characteristic of the Health System Resilience Index among the Integration and Resource Availability and Access characteristics to make the index more suitably tailored for immunisation programmes.

Given the central role of communication and public trust in establishing immunisation programme resilience,⁶⁵ it may not be surprising that Integration and Awareness were very commonly identified and discussed features of immunisation programmes relevant to resilience during times of crisis. Self-regulation was the resilience characteristic discussed least often, emphasising internal regulation of systems rather than by independent bodies. One important exception to this characteristic is the need for independent National Immunisation Technical Advisory Groups (NITAGs) which we list under

'Resource Availability and Access'. Recommendations made by independent and credible expert groups, such as NITAGs, play a vital role in strengthening the governance of immunisation programmes which is critical for their self-regulation.⁶⁶ One hundred and seventy-two countries have formally established NITAGs to, among other things, provide immunisation programme assessments that are independent of the immunisation programme itself. A balance between self-regulation and the existence of NITAGs that provide independent recommendations are critical to a resilient immunisation system.

Due to the evidence-based approach taken in this review, there will inevitably be important topics regarding immunisation programme resilience that are omitted due to a current lack of research. We identified a single study that adopted an experimental randomised trial study design, where ongoing conflict in three regions in Pakistan was the crisis in question, and the different study arms involved various vaccination strategies under the control of the researchers.³⁰ However, the overwhelming majority of studies reviewed adopted observational study designs, where the researchers did not have control over exposures.²⁰ Given the challenging nature of studying immunisation programmes during times of crisis in locations dealing with disruptions to their programmes, the predominance of observational study designs was unsurprising. Additionally, with environmental crises (eg, disease outbreaks) and social crises (eg, loss of trust and incitement of fear) being the dominant research focus and most studies being conducted in Africa, Asia and Europe, we identified several evidence gaps that could limit our understanding of immunisation programme resilience.

Examples of evidence gaps are the roles of economic and technological crises on immunisation programmes. The lack of literature might have been due to limiting our searches to studies published in peer-reviewed journals, as there may be relevant primary empirical studies in the grey literature. This limitation could be addressed in future reviews with a more refined and targeted research question. Additionally, evidence gaps may be due to the 10-year limit on research publications used in the present review. There is evidence of the impact of the 2008 global financial crisis on immunisation programmes, however, this topic appears to have received limited research attention.⁶⁷ Regarding technological crises, cyberattacks on healthcare IT systems are becoming more common, for example, WannaCry ransomware attack on the UK's National Health Service IT systems in 2017 and the recent Conti ransomware attack on the Ireland's Health Service Executive IT systems in 2021. While we did not identify research on the impact of technological crises on immunisation programmes in the academic literature, the rise in ransomware attacks during the COVID-19 pandemic⁶⁸ highlights the importance of strong cybersecurity⁶⁹ to immunisation programme resilience.

Another evidence gap that has come to the forefront during the COVID-19 pandemic is vaccine inequity across

communities within a country.⁷⁰ While vaccination equity is a valuable goal of immunisation programmes, it may also be a feature of immunisation programme resilience.^{58,70} The topic of vaccination equity may be relevant under the characteristics of Resource Availability and Access, or Integration due to the association between vaccination hesitancy and socioeconomic class,^{71,72} or Awareness to emphasise the benefit of monitoring for potential vaccination disparities across populations. Alternatively, it may require assessing equity in each immunisation programme resilience characteristic. Based on our search criteria, primary empirical research on this topic is currently lacking.

Given challenges in generating novel primary research findings during times of crisis, the bottom-up construction of a data-driven and evidence-based Immunisation Programme Resilience Framework may require adaptations and supplementations by top-down expert opinion. This approach will help to expand or refine the content within each topic to compensate for evidence gaps.

Due to the diversity of healthcare systems, the Health System Resilience Index does not recommend using the framework to create national standards that benchmark activities against external criteria. Immunisation programmes are similarly complex, and we did not identify potential national or sub-national benchmarks within an Immunisation Programme Resilience Framework since the empirical evidence required to support benchmarking standards is beyond the scope of this review. Rather, this framework could inform the development of a tool to conduct an initial assessment of the resilience of an immunisation programme and identify potential areas for improvement; there is an opportunity to leverage these findings to develop a tool based on empirical evidence and expert opinion. This can in turn be used to inform evidence-based decision-making and secure funding for the necessary resources to improve and sustain, where appropriate, immunisation programme resilience.

In addition to the search strategy limitations discussed above, the overwhelming reliance on observational study designs in this literature base limits the ability to make strong causal arguments regarding relations between outcomes and assumed exposures from observational studies.⁷³ Additionally, the lack of identified research during times of economic and technological crises, as well as limited research originating from many geographical locations, potentially limits the generalisability of the proposed framework to these contexts. Further, an evidence-based approach to establishing a framework limits the resilience characteristics and topics to those addressed in the literature. Ongoing assessments of relevant literature under circumstances beyond those covered in this review will likely result in further improvement and refinement of the proposed framework, and further development can also proceed using top-down theory-based appraisal and supplementation by experts. Despite these limitations, identifying key characteristics of resilient immunisation programmes will help inform

our understanding of how to improve crisis readiness for the benefit of public health.

Conclusion

Conducting this scoping review provided an opportunity to outline a framework that may be relevant to creating resilient immunisation programmes. Nevertheless, for this framework to be useful in practice, it needs to have input from multiple stakeholders, which include national governments, regional bodies, vaccine developers, health-care professionals, civil society and individuals involved in immunisation programme implementation. By seeking expert advice from such groups, an over-reliance on top-down expert opinion can be avoided and evidence gaps filled. Developing this framework may allow the creation of a tool to inform evidence-based decision-making and secure appropriate funding to ensure immunisation programmes not only optimise functioning during times of crisis but identify weak points needing further enhancement to ensure long-term resilience.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. All data and code underlying the results are available for download using the following Zenodo link: <https://doi.org/10.5281/zenodo.11219987>.

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